

CLAIMS

(1) A rectifying device, comprising:

a pair of electrodes; and

a carrier transporter arranged between the pair of electrodes and composed of one or multiple carbon nanotubes, characterized in that a first connection configuration between one electrode of the pair of electrodes and the carrier transporter and a second connection configuration between the other electrode of the pair of electrodes and the carrier transporter are made different from each other in such a manner that a first interface between the one electrode and the carrier transporter and a second interface between the other electrode and the carrier transporter have different barrier levels.

(2) A rectifying device according to claim 1, characterized in that the carrier transporter is composed of multiple carbon nanotubes.

(3) A rectifying device according to claim 2, characterized in that the carrier transporter is formed by a carbon nanotube structure having a network structure in which the multiple carbon nanotubes mutually cross-link.

(4) A rectifying device according to claim 1, characterized

in that an oxide layer is allowed to be present on at least one of the first interface and the second interface in such a manner that the first interface and the second interface have different barrier levels.

(5) A rectifying device according to claim 4, characterized in that the oxide layer comprises a metal oxide film or an oxide film of a semiconductor.

(6) A rectifying device according to claim 4, characterized in that the oxide layer comprises a metal oxide film, and the metal oxide film is composed of an oxide of a material composing the one electrode.

(7) A rectifying device according to claim 6, characterized in that the pair of electrodes is composed of different materials.

(8) A rectifying device according to claim 7, characterized in that a material composing one electrode of the pair of electrodes comprises at least one metal selected from the group consisting of titanium, aluminum, silver, copper, silicon that is made conductive, iron, tantalum, niobium, zinc, tungsten, tin, nickel, magnesium, indium, chromium, palladium, molybdenum, and cobalt, or an alloy thereof.

(9) A rectifying device according to claim 4, characterized in that the oxide layer is composed of at least one selected from the group consisting of aluminum oxide, silicon dioxide, copper oxide, silver oxide, titanium oxide, zinc oxide, tin oxide, nickel oxide, magnesium oxide, indium oxide, chromium oxide, lead oxide, manganese oxide, iron oxide, palladium oxide, tantalum oxide, tungsten oxide, molybdenum oxide, vanadium oxide, cobalt oxide, hafnium oxide, and lanthanum oxide.

(10) A rectifying device according to claim 7, characterized in that the one electrode is composed of a material having an ionization tendency higher than that of the other electrode.

(11) A rectifying device according to claim 1, characterized in that a material for the one electrode and a material for the other electrode are made different in such a manner that the first interface and the second interface have different barrier levels.

(12) A rectifying device according to claim 11, characterized in that the materials composing the one electrode and the other electrode each independently comprise at least one metal selected from the group consisting of aluminum, silver, copper, silicon that is made conductive, gold, platinum, titanium, zinc, nickel, tin,

magnesium, indium, chromium, manganese, iron, lead, palladium, tantalum, tungsten, molybdenum, vanadium, cobalt, hafnium, and lanthanum, or an alloy thereof.

(13) A rectifying device according to claim 11, characterized in that the material composing the other electrode comprises at least one metal selected from the group consisting of gold, titanium, iron, nickel, tungsten, silicon that is made conductive, chromium, niobium, cobalt, molybdenum, and vanadium, or an alloy thereof.

(14) A rectifying device according to claim 11, characterized in that a degree of adhesion between the one electrode and the carrier transporter at the first interface is smaller than a degree of adhesion between the other electrode and the carrier transporter at the second interface.

(15) A rectifying device according to claim 1, characterized in that a surface of the carrier transporter is modified at the first interface or the second interface to generate a difference between a degree of adhesion between the one electrode and the carrier transporter at the first interface and a degree of adhesion between the other electrode and the carrier transporter at the second interface.

(16) A rectifying device according to claim 1, characterized in that an adhesion force adjusting layer is allowed to be present on at least one of the first interface and the second interface to generate a difference between a degree of adhesion between the one electrode and the carrier transporter at the first interface and a degree of adhesion between the other electrode and the carrier transporter at the second interface.

(17) A rectifying device according to claim 3, characterized in that the carbon nanotube structure is obtained by chemically bonding functional groups bonded to multiple carbon nanotubes to form cross-linked sites.

(18) A rectifying device according to claim 17, characterized in that the multiple carbon nanotubes mainly comprise single-wall carbon nanotubes.

(19) A rectifying device according to claim 17, characterized in that the multiple carbon nanotubes mainly comprise multi-wall carbon nanotubes.

(20) A rectifying device according to claim 17, characterized in that the cross-linked sites each comprise a chemical structure selected from the group consisting of $(-\text{COO}(\text{CH}_2)_2\text{OCO}-)$,

-COOCH₂CHOHCH₂OCO-, -COOCH₂CH(OCO-)CH₂OH, -COOCH₂CH(OCO-)CH₂OCO-,
and -COO-C₆H₄-COO-.

(21) A rectifying device according to claim 3, characterized in that the cross-linked sites each comprise a chemical structure selected from the group consisting of -COOCO-, -O-, -NHCO-, -COO-, -NCH-, -NH-, -S-, -O-, -NHCOO-, and -S-S-.

(22) A rectifying device according to claim 17, characterized in that a solution containing multiple carbon nanotubes to which functional groups are bonded to form the cross-linked sites by chemically bonding the functional groups of the multiple carbon nanotubes.

(23) A rectifying device according to claim 17, characterized in that a solution containing multiple carbon nanotubes to which functional groups are bonded and a cross-linking agent capable of prompting a cross-linking reaction with the functional groups is cured to subject the functional groups and the cross-linking agent to a cross-linking reaction, to thereby form the cross-linked sites.

(24) A rectifying device according to claim 23, characterized in that the cross-linking agent comprises a non-self-polymerizable cross-linking agent.

(25) A rectifying device according to claim 17, characterized in that the cross-linked sites have structures formed by chemical bonding of the functional groups.

(26) A rectifying device according to claim 25, characterized in that a reaction that forms the chemical bonding comprises a reaction selected from the group consisting of dehydration condensation, a substitution reaction, an addition reaction, and an oxidative reaction.

(27) A rectifying device according to claim 2, characterized in that the carrier transporter is laminar, and the carbon nanotube structure is patterned into a predetermined shape.

(28) A rectifying device according to claim 27, characterized in that:

the barrier level at the first interface is higher than the barrier level at the second interface; and

a width of a surface of the one electrode is equal to or greater than a width of the carrier transporter at an interface between the one electrode and the carrier transporter.

(29) A rectifying device according to claim 28, characterized

in that the first connection configuration is obtained by allowing an oxide layer to be present at the first interface.

(30) A rectifying device according to claim 1, characterized by further comprising a sealing member for sealing at least the first interface against external air.

(31) An electronic circuit, characterized by comprising:
the rectifying device according to claim 1; and
a flexible base body having the rectifying device formed on its surface.

(32) A method of manufacturing a rectifying device including:
a base body; a pair of electrodes arranged on a surface of the base body; and a carrier transporter arranged between the pair of electrodes and composed of one or multiple carbon nanotubes, characterized by comprising a connection configuration forming step of forming a first connection configuration between one electrode of the pair of electrodes and the carrier transporter and a second connection configuration between the other electrode of the pair of electrodes and the carrier transporter into different configurations in such a manner that a first interface between the one electrode and the carrier transporter and a second interface between the other electrode and the carrier transporter have

different barrier levels.

(33) A method of manufacturing a rectifying device according to claim 32, characterized in that the connection configuration forming step includes an oxide layer forming step of forming, at the first interface between the one electrode and the carrier transporter, an oxide layer such that the first interface has a barrier level different from that of the second interface between the other electrode and the carrier transporter.

(34) A method of manufacturing a rectifying device according to claim 33, characterized in that the oxide layer forming step comprises a step including: arranging an oxide precursor layer composed of a material that can be oxidized at the first interface; and oxidizing the oxide precursor layer.

(35) A method of manufacturing a rectifying device according to claim 34, characterized in that:

the carrier transporter is formed by a carbon nanotube structure having a network structure in which multiple carbon nanotubes mutually cross-link; and

the oxide layer forming step comprises a step including: forming the oxide precursor layer so as to be in contact with the carrier transporter; and oxidizing the oxide precursor layer.

(36) A method of manufacturing a rectifying device according to claim 33, characterized in that the oxide layer forming step comprises a step including: forming one electrode of the pair of electrodes from a material that can be oxidized; and oxidizing a surface of the one electrode at the first interface to form an oxide layer.

(37) A method of manufacturing a rectifying device according to claim 36, characterized in that:

the carrier transporter is formed by a carbon nanotube structure having a network structure in which multiple carbon nanotubes mutually cross-link; and

the oxide layer forming step comprises a step including: forming the one electrode so as to be in contact with the carrier transporter; and oxidizing the one electrode at a surface where the electrode and the carrier transporter are in contact with each other.

(38) A method of manufacturing a rectifying device according to claim 36, characterized in that a material composing one electrode of the pair of electrodes comprises at least one metal selected from the group consisting of aluminum, silver, copper, silicon that is made conductive, titanium, zinc, nickel, tin, magnesium, indium,

chromium, manganese, iron, lead, palladium, tantalum, tungsten, molybdenum, vanadium, cobalt, hafnium, and lanthanum, or an alloy thereof.

(39) A method of manufacturing a rectifying device according to claim 33, characterized in that the other electrode is composed of a material having an ionization tendency lower than that of the one electrode.

(40) A method of manufacturing a rectifying device according to claim 33, characterized in that a material composing the other electrode comprises at least one metal selected from the group consisting of gold, titanium, iron, nickel, tungsten, silicon that is made conductive, chromium, niobium, cobalt, molybdenum, and vanadium, or an alloy thereof.

(41) A method of manufacturing a rectifying device according to claim 32, characterized in that the connection configuration forming step includes a step of forming the pair of electrodes from different materials.

(42) A method of manufacturing a rectifying device according to claim 32, characterized in that the connection configuration forming step includes a step of modifying a surface of the carrier

transporter at the first interface or the second interface to generate a difference between a degree of adhesion between the one electrode and the carrier transporter at the first interface and a degree of adhesion between the other electrode and the carrier transporter at the second interface.

(43) A method of manufacturing a rectifying device according to claim 32, characterized in that the connection configuration forming step includes a step of forming an adhesion force adjusting layer on at least one of the first interface and the second interface to generate a difference between a degree of adhesion between the one electrode and the carrier transporter at the first interface and a degree of adhesion between the other electrode and the carrier transporter at the second interface.

(44) A method of manufacturing a rectifying device according to claim 32, characterized in that the carrier transporter is formed by a network structure in which multiple carbon nanotubes which are not chemically bonded together are entangled.

(45) A method of manufacturing a rectifying device according to claim 32, characterized in that the carrier transporter is composed of a carbon nanotube structure having a network structure in which the multiple carbon nanotubes mutually cross-link.

(46) A method of manufacturing a rectifying device according to claim 32, further comprising, prior to the connection formation forming step, a carrier transporter forming step of forming the carrier transporter, characterized in that the carrier transporter forming step includes:

a supplying step of supplying the surface of the base body with multiple carbon nanotubes having functional groups; and

a cross-linking step of cross-linking the functional groups via cross-linked sites to form the carbon nanotube structure having the network structure.

(47) A method of manufacturing a rectifying device according to claim 46, characterized in that:

the supplying step includes an applying step of applying a solution containing the carbon nanotubes having the functional groups to the surface of the base body; and

the carbon nanotube structure is filmy.

(48) A method of manufacturing a rectifying device according to claim 46, characterized in that the multiple carbon nanotubes mainly comprise single-wall carbon nanotubes.

(49) A method of manufacturing a rectifying device according

to claim 46, characterized in that the multiple carbon nanotubes mainly comprise multi-wall carbon nanotubes.

(50) A method of manufacturing a rectifying device according to claim 46, characterized in that the supplying step includes supplying a cross-linking agent for cross-linking the functional groups to the surface of the base body.

(51) A method of manufacturing a rectifying device according to claim 50, characterized in that the cross-linking agent comprises a non-self-polymerizable cross-linking agent.

(52) A method of manufacturing a rectifying device according to claim 46, characterized in that:

the functional groups comprise at least one functional group selected from the group consisting of -OH, -COOH, -COOR (where R represents a substituted or unsubstituted hydrocarbon group), -COX (where X represents a halogen atom), -NH₂, and -NCO; and

the cross-linking agent is capable of prompting a cross-linking reaction with the selected functional group.

(53) A method of manufacturing a rectifying device according to claim 50, characterized in that:

the cross-linking agent comprises at least one cross-linking

agent selected from the group consisting of a polyol, a polyamine, a polycarboxylic acid, a polycarboxylate, a polycarboxylic acid halide, a polycarbodiimide, and a polyisocyanate; and

each of the functional groups is capable of prompting a cross-linking reaction with the selected cross-linking agent.

(54) A method of manufacturing a rectifying device according to claim 50, characterized in that:

the functional groups comprise at least one functional group selected from the group consisting of -OH, -COOH, -COOR (where R represents a substituted or unsubstituted hydrocarbon group), -COX (where X represents a halogen atom), -NH₂, and -NCO;

the cross-linking agent comprises at least one cross-linking agent selected from the group consisting of a polyol, a polyamine, a polycarboxylic acid, a polycarboxylate, a polycarboxylic acid halide, a polycarbodiimide, and a polyisocyanate; and

a combination of the selected functional group and the selected cross-linking agent is capable of prompting a mutual cross-linking reaction.

(55) A method of manufacturing a rectifying device according to claim 46, characterized in that each of the functional groups comprises -COOR (where R represents a substituted or unsubstituted hydrocarbon group).

(56) A method of manufacturing a rectifying device according to claim 55, characterized in that the cross-linking agent comprises a polyol.

(57) A method of manufacturing a rectifying device according to claim 56, characterized in that the cross-linking agent comprises at least one selected from the group consisting of glycerin, ethylene glycol, butenediol, hexynediol, hydroquinone, and naphthalenediol.

(58) A method of manufacturing a rectifying device according to claim 46, characterized in that a reaction for cross-linking the functional groups in the cross-linking step comprises a reaction for chemically bonding the functional groups.

(59) A method of manufacturing a rectifying device according to claim 58, characterized in that the supplying step includes supplying an additive that forms the chemical bonding of the functional groups to the surface of the base body.

(60) A method of manufacturing a rectifying device according to claim 59, characterized in that the reaction comprises dehydration condensation and the additive comprises a condensation agent.

(61) A method of manufacturing a rectifying device according to claim 60, characterized in that the functional groups comprise at least one functional group selected from the group consisting of -COOR (where R represents a substituted or unsubstituted hydrocarbon group), -COOH, -COX (where X represents a halogen atom), -OH, -CHO, and -NH₂.

(62) A method of manufacturing a rectifying device according to claim 60, characterized in that each of the functional groups comprises -COOH.

(63) A method of manufacturing a rectifying device according to claim 60, characterized in that the condensation agent comprises one selected from the group consisting of sulfuric acid, N-ethyl-N'-(3-dimethylaminopropyl)carbodiimide, and dicyclohexyl carbodiimide.

(64) A method of manufacturing a rectifying device according to claim 59, wherein the reaction comprises a substitution reaction and the additive comprises a base.

(65) A method of manufacturing a rectifying device according to claim 64, wherein the functional groups comprise at least one functional group selected from the group consisting of -NH₂, -X (where

X represents a halogen atom), -SH, -OH, -OSO₂CH₃, and -OSO₂(C₆H₄)CH₃.

(66) A method of manufacturing a rectifying device according to claim 64, characterized in that the base comprises one selected from the group consisting of sodium hydroxide, potassium hydroxide, pyridine, and sodium ethoxide.

(67) A method of manufacturing a rectifying device according to claim 58, characterized in that the reaction comprises an addition reaction.

(68) A method of manufacturing a rectifying device according to claim 67, characterized in that the functional groups comprise at least one chosen from -OH and -NCO.

(69) A method of manufacturing a rectifying device according to claim 59, characterized in that the reaction comprises an oxidative reaction.

(70) A method of manufacturing a rectifying device according to claim 69, characterized in that each of the functional groups comprises -SH.

(71) A method of manufacturing a rectifying device according

to claim 69, characterized in that the additive comprises an oxidative reaction accelerator.

(72) A method of manufacturing a rectifying device according to claim 71, characterized in that the oxidative reaction accelerator comprises iodine.

(73) A method of manufacturing a rectifying device according to claim 32, characterized in that:

the carrier transporter is formed by a carbon nanotube structure having a network structure in which the multiple carbon nanotubes mutually cross-link; and

the method further comprises a patterning step of patterning the carbon nanotube structure into a pattern corresponding to the carrier transporter.

(74) A method of manufacturing a rectifying device according to claim 73, characterized in that the patterning step comprises a step in which the carbon nanotube structure in a region on the surface of the base body other than a pattern corresponding to the carrier transporter is subjected to dry etching to remove the carbon nanotube structure in the region, whereby the carbon nanotube structure is patterned into a pattern corresponding to the carrier transporter.

(75) A method of manufacturing a rectifying device according to claim 74, characterized in that the patterning step includes:

a resist layer forming step of forming a resist layer above the carbon nanotube structure in a region on the surface of the base body having the pattern corresponding to the carrier transporter; and

a removing step of removing the carbon nanotube structure exposed in a region other than the region by subjecting a surface of the base body on which the carbon nanotube structure and the resist layer are laminated to dry etching.

(76) A method of manufacturing a rectifying device according to claim 75, characterized in that, in the removing step, the surface of the base body on which the carbon nanotube structure and the resist layer are laminated is irradiated with an oxygen molecule radical.

(77) A method of manufacturing a rectifying device according to claim 76, characterized in that oxygen molecules are irradiated with ultraviolet rays to generate an oxygen molecule radical, which is used as a radical with which the surface of the base body on which the carbon nanotube structure and the resist layer are laminated is irradiated.

(78) A method of manufacturing a rectifying device according to claim 75, characterized in that the patterning step further includes a resist layer peeling-off step of peeling off the resist layer formed in the resist layer forming step subsequent to the removing step.

(79) A method of manufacturing a rectifying device according to claim 75, characterized in that the resist layer comprises a resin layer.

(80) A method of manufacturing a rectifying device according to claim 74, characterized in that the patterning step comprises a step of patterning the carbon nanotube structure into the pattern corresponding to the carrier transporter by selectively irradiating the carbon nanotube structure in a region of the surface of the base body other than the region having the pattern corresponding to the carrier transporter with an ion beam of a gas molecule to remove the carbon nanotube structure in the region.